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Fukuda et al.

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(54) **LIQUID EJECTION HEAD AND LIQUID EJECTION APPARATUS**

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B41J 2/19 (2006.01)
B41J 2/14 (2006.01)

(52) **U.S. Cl.**
CPC .. ***B41J 2/175*** (2013.01); ***B41J 2/14*** (2013.01); ***B41J 2/19*** (2013.01); *B41J 2002/14403* (2013.01)

(58) **Field of Classification Search**
USPC 347/7, 19, 84, 85, 92
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,505,923	B1 *	1/2003	Yamamoto et al.	347/85
6,520,630	B1 *	2/2003	Oda et al.	347/85
6,726,313	B1 *	4/2004	Oda et al.	347/85
6,799,841	B2	10/2004	Iri et al.	
6,976,753	B2	12/2005	Kuwabara et al.	
7,185,977	B2 *	3/2007	Kyogoku et al.	347/86
7,380,921	B2	6/2008	Nanjo et al.	
7,434,916	B2	10/2008	Mukai et al.	
7,537,318	B2	5/2009	Fujii et al.	
8,020,983	B2 *	9/2011	Nishimori	347/92

(Continued)

FOREIGN PATENT DOCUMENTS

JP	08-336985	A	12/1996
JP	2001-187459	A	7/2001

(Continued)

OTHER PUBLICATIONS

Search Report in European Patent Application No. 14160834.9, dated May 26, 2014.

(Continued)

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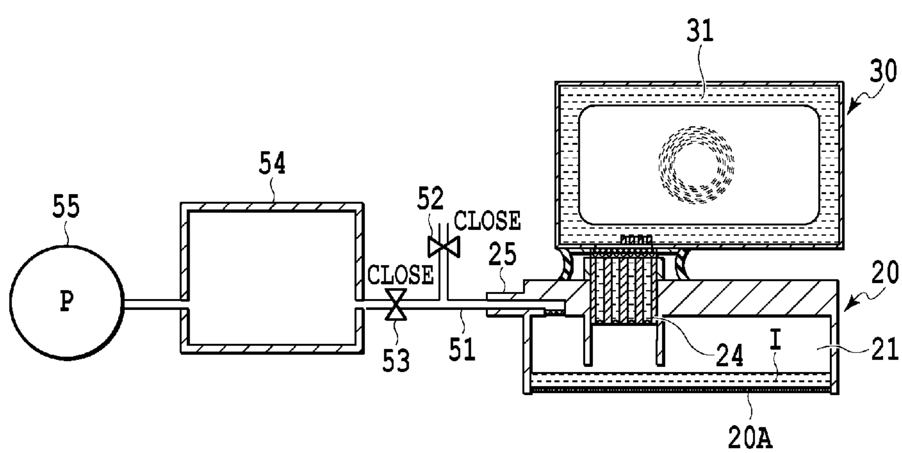
(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

A liquid ejection head is capable of ejecting a liquid through an ejection port, the liquid being supplied from a liquid container with a negative pressure generating section. The liquid ejection head comprises a liquid chamber configured to contain the liquid, a liquid supply section configured to allow the liquid to be supplied from the liquid container to the liquid chamber, and an opening configured to communicate with the liquid chamber and to enable the liquid and/or a gas to flow into the liquid chamber through the opening.

26 Claims, 13 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

8,348,365	B2 *	1/2013	Huang et al.	347/7
2005/0157041	A1	7/2005	Inoue	
2011/0316907	A1	12/2011	Huang et al.	
2012/0098898	A1	4/2012	Park et al.	
2013/0208044	A1	8/2013	Matsumoto et al.	
2013/0286116	A1	10/2013	Takahashi et al.	
2014/0285586	A1	9/2014	Fukuda et al.	

FOREIGN PATENT DOCUMENTS

JP	2003-039705	A	2/2003
JP	2003-080714	A	3/2003
JP	2004-122500	A	4/2004
JP	2004-188720	A	7/2004
JP	2005-103858	A	4/2005
JP	2005-231351	A	9/2005
JP	2005-279962	A	10/2005
JP	2009-040062	A	2/2009
JP	2009-220059	A	10/2009
JP	2010-274607	A	12/2010
JP	2011-000823	A	1/2011
JP	2011-201149	A	10/2011
JP	2011-235605	A	11/2011
JP	2013-129163	A	7/2013
JP	2015-127491	A	9/2015
JP	6806341	B2	11/2015

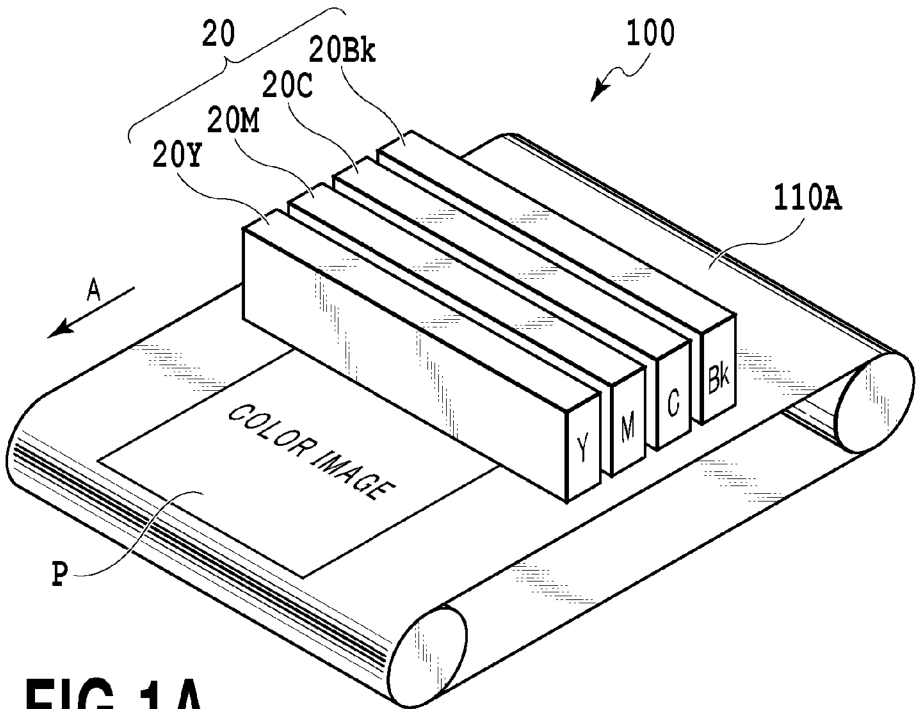
OTHER PUBLICATIONS

Office Action in Japanese Patent Application No. 2014-005229, dated Feb. 17, 2015.

Office Action in Japanese Patent Application No. 2014-058462, dated Aug. 18, 2015.

Office Action in Japanese Patent Application No. 2015-173722, dated Apr. 26, 2016.

* cited by examiner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20Bk
20C
20M
20Y
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110A
A
Y
M
C
Bk
COLOR IMAGE
P

FIG.1A

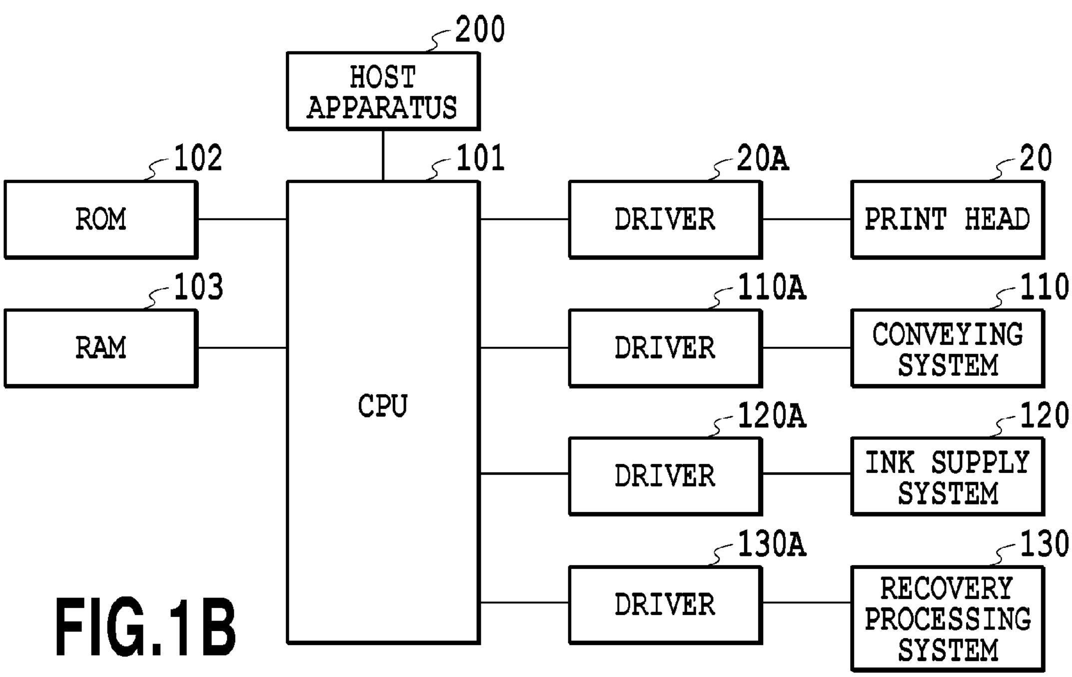

200
HOST APPARATUS
102
ROM
103
RAM
101
CPU
20A
DRIVER
110A
DRIVER
120A
DRIVER
130A
DRIVER
20
PRINT HEAD
110
CONVEYING SYSTEM
120
INK SUPPLY SYSTEM
130
RECOVERY PROCESSING SYSTEM

FIG.1B

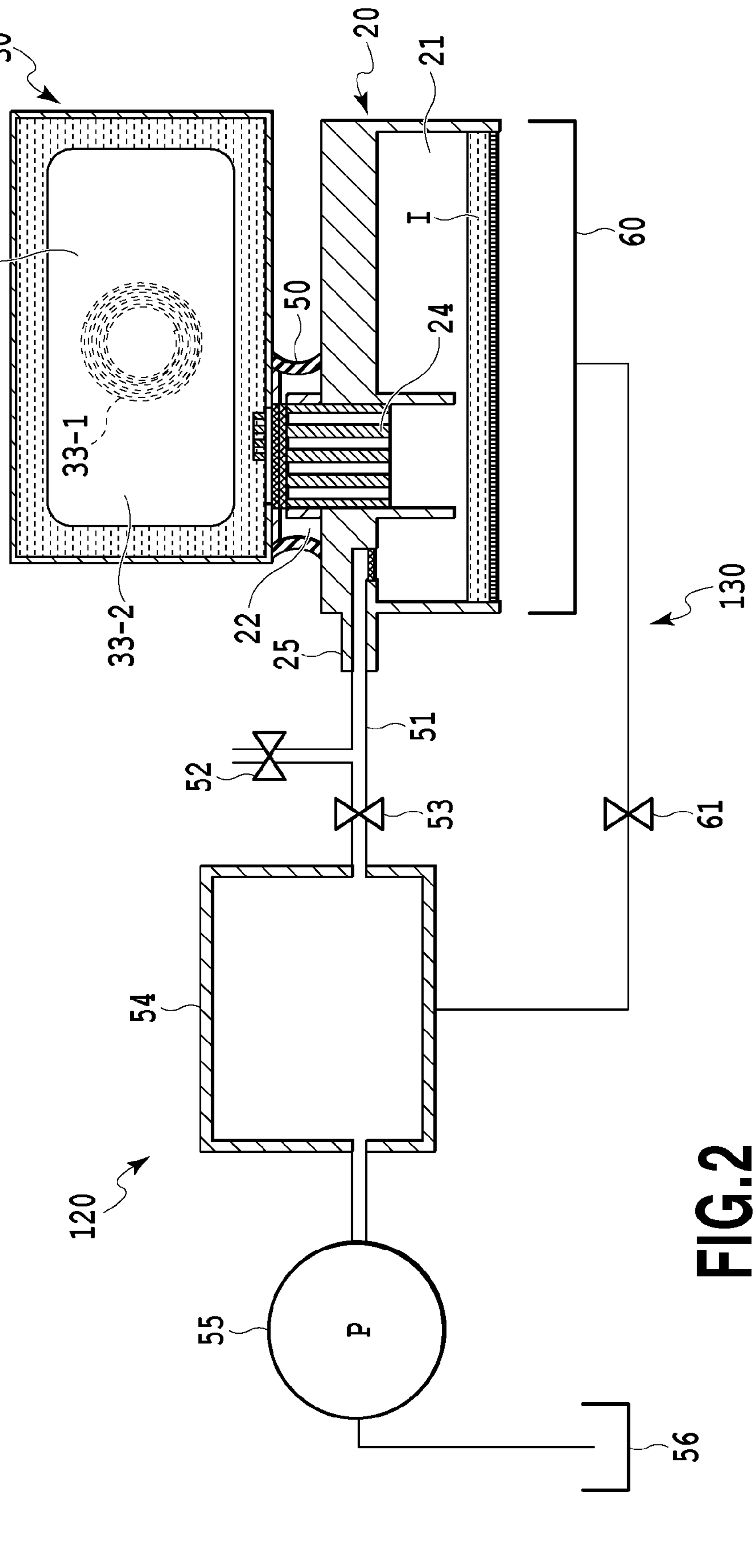


FIG.2

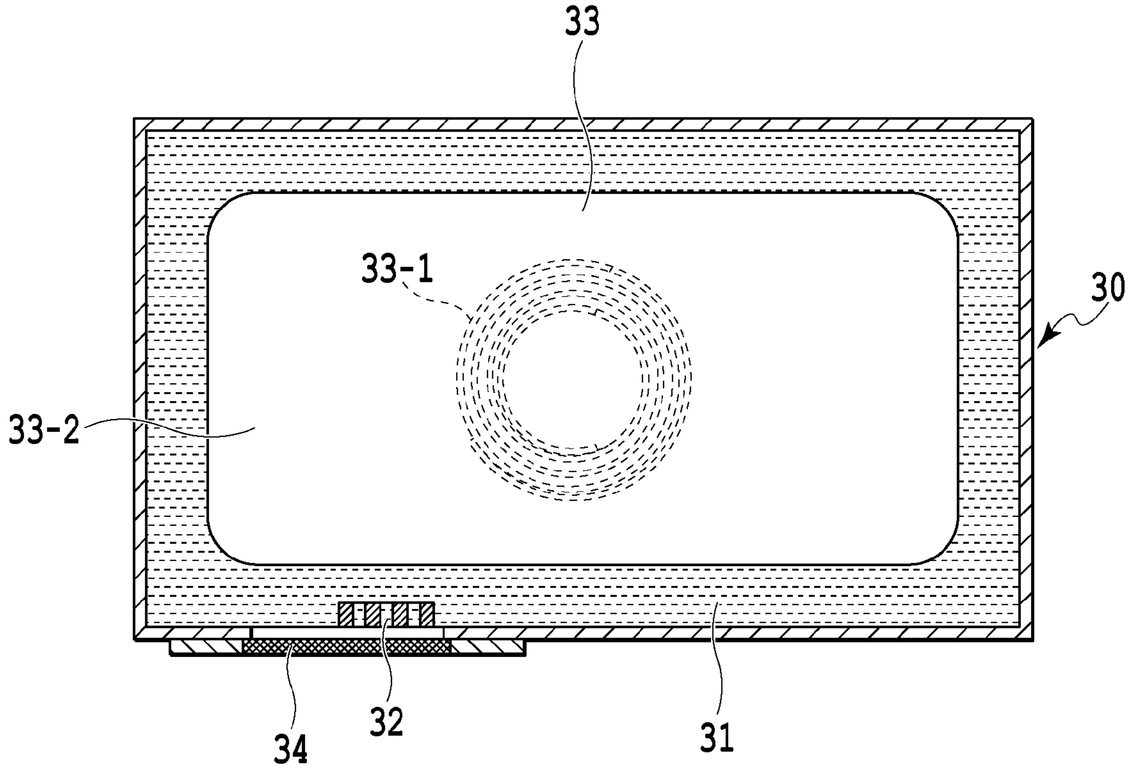


FIG.3

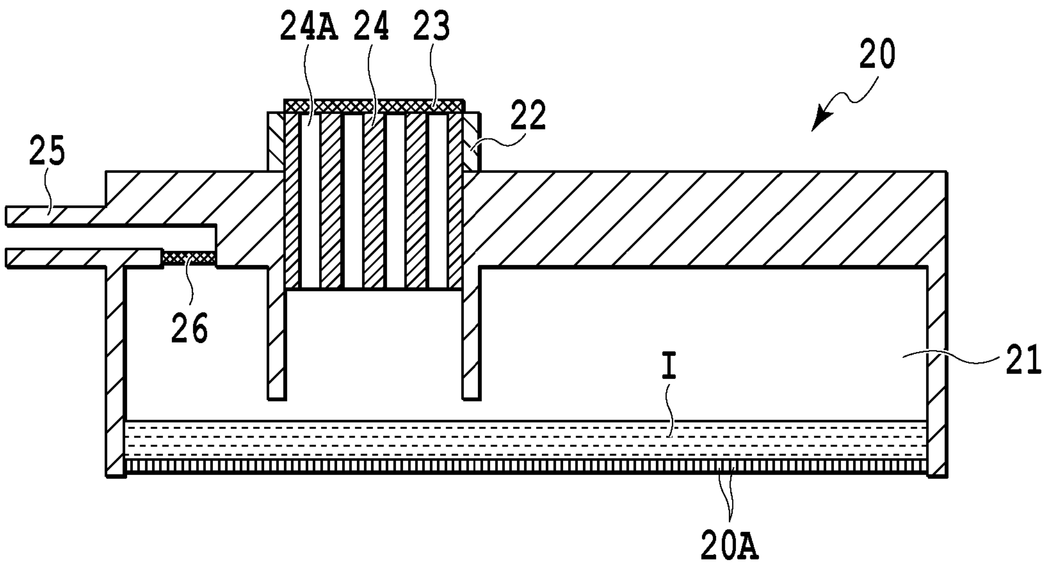


FIG.4

FIG.5A

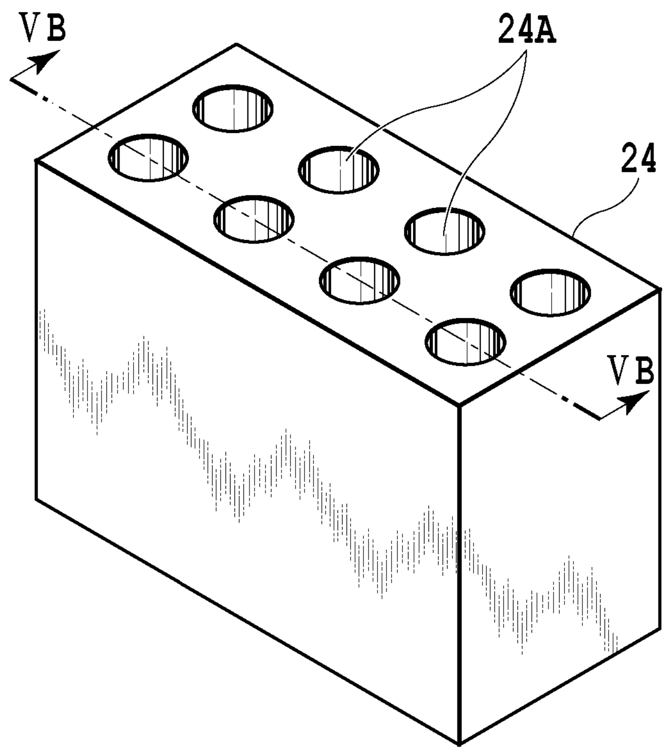
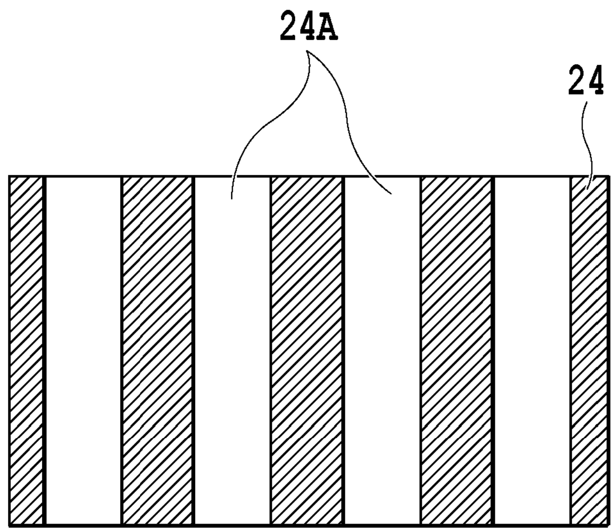


FIG.5B



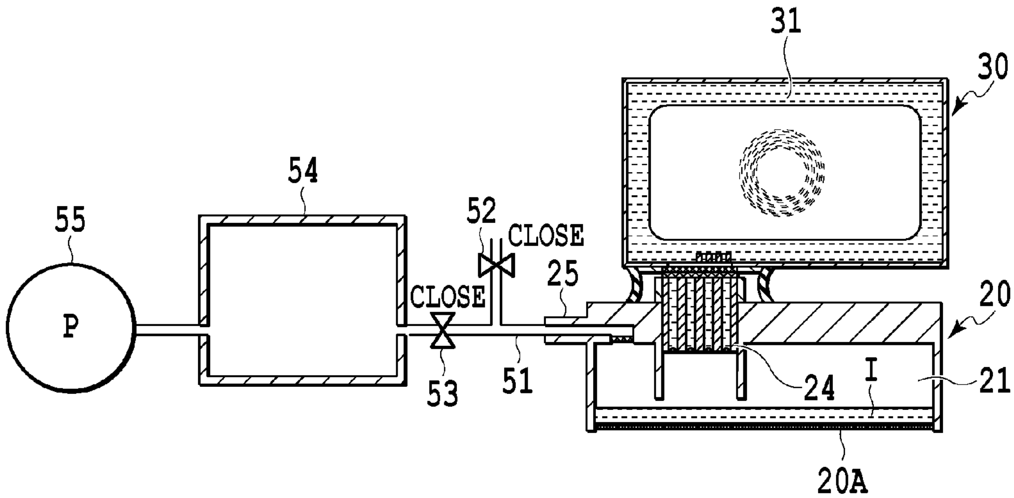

31
30
54
55
52
CLOSE
25
20
P
CLOSE
53
51
24
I
21
20A

FIG.6A

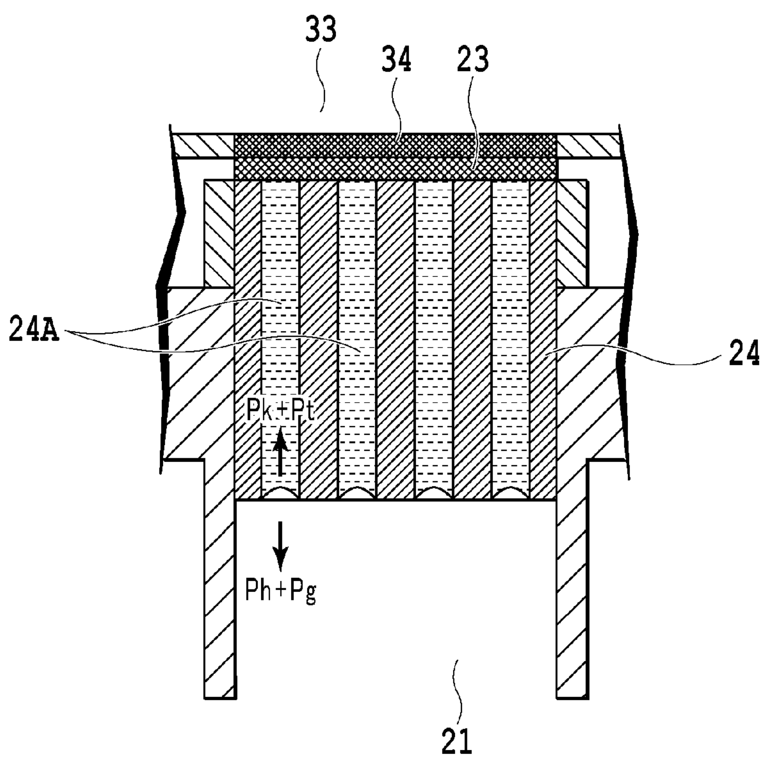

33
34
23
24A
24
Pk+Pt
Ph+Pg
21

FIG.6B

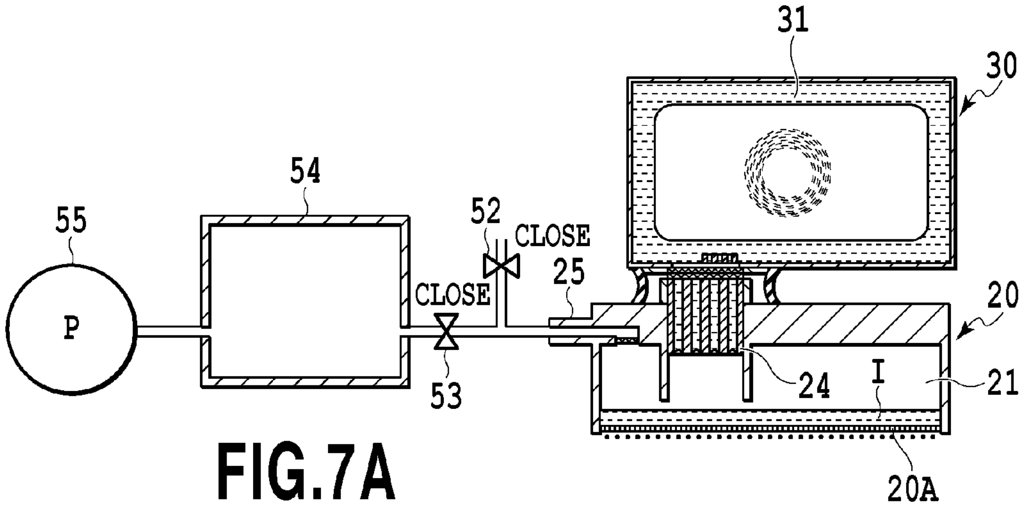


FIG.7A

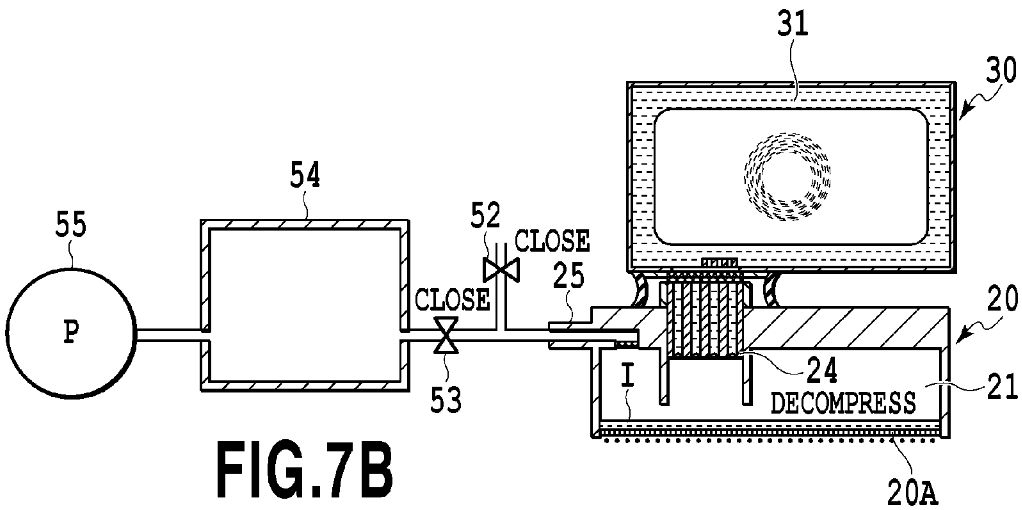


FIG.7B

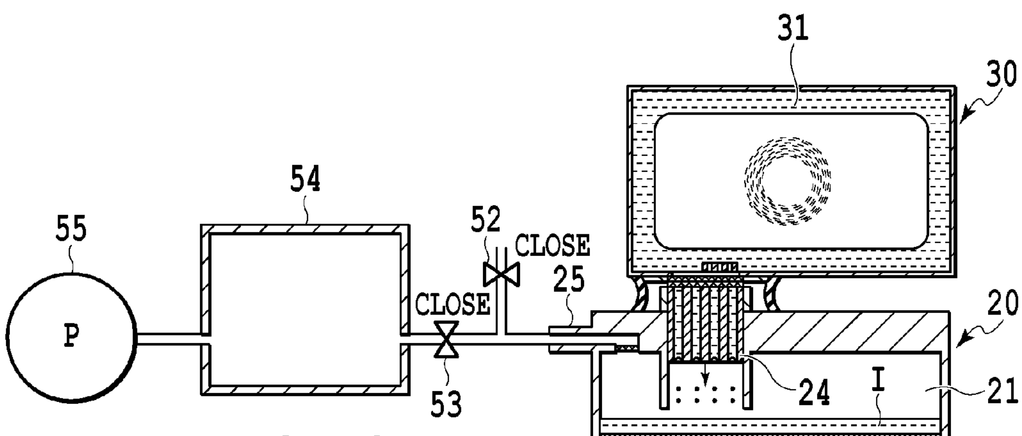


FIG.7C

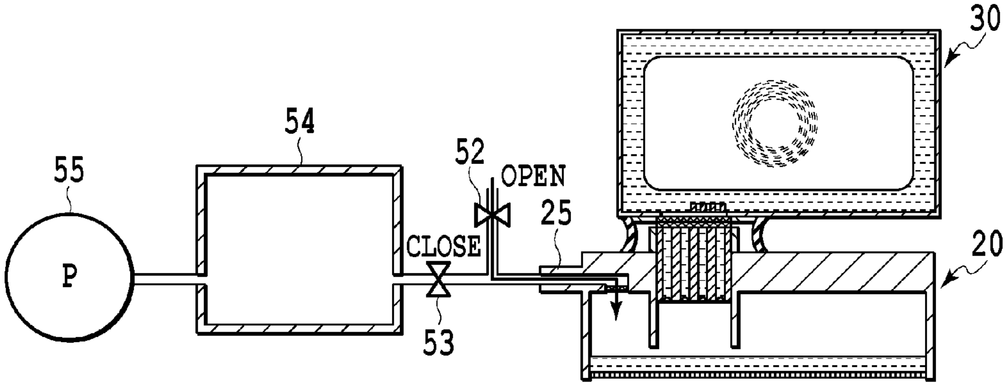


FIG.8A

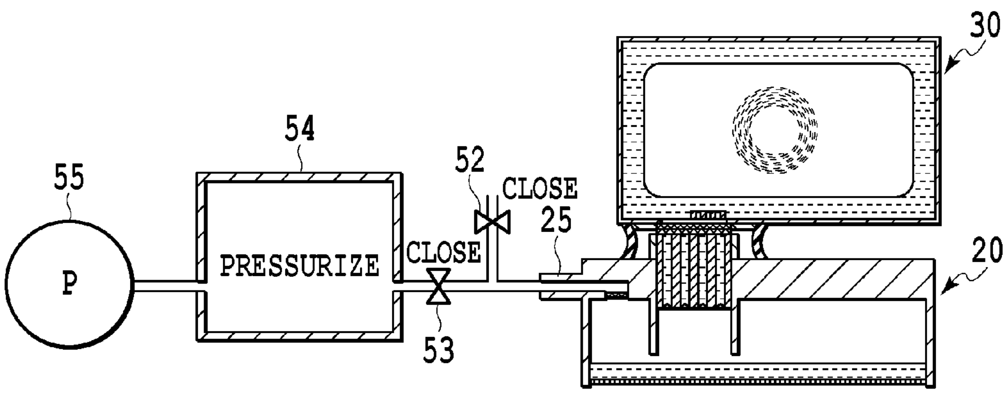


FIG.8B

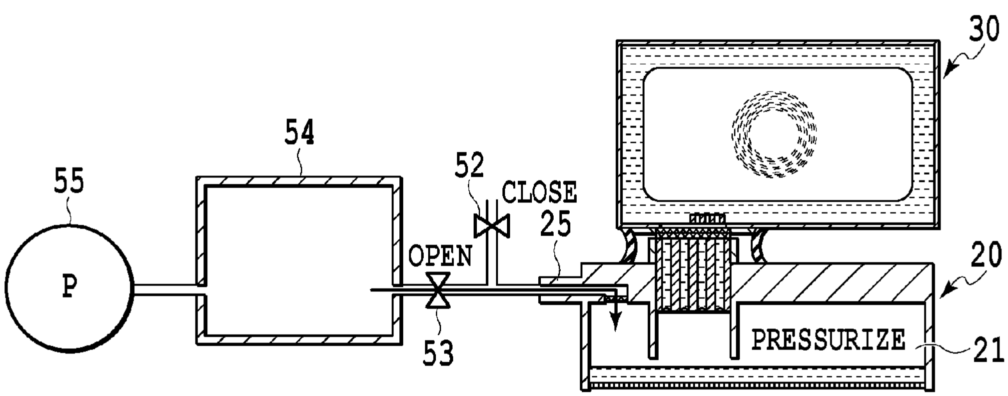


FIG.8C

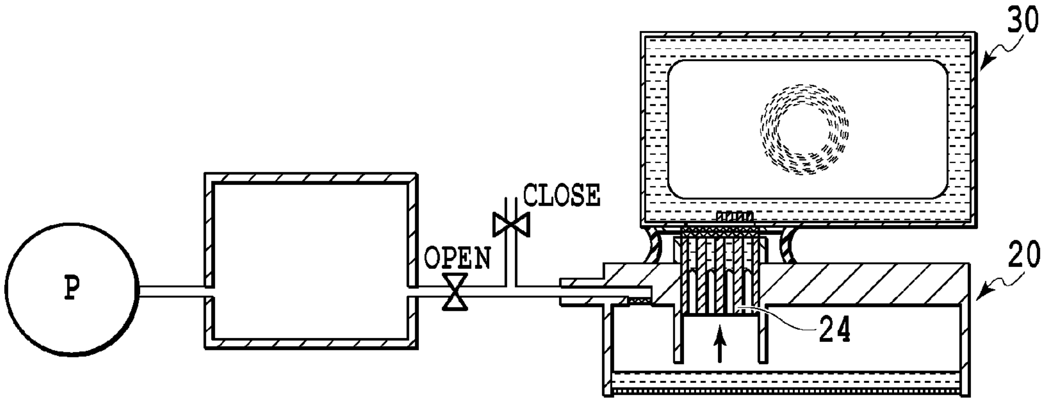


FIG.9A

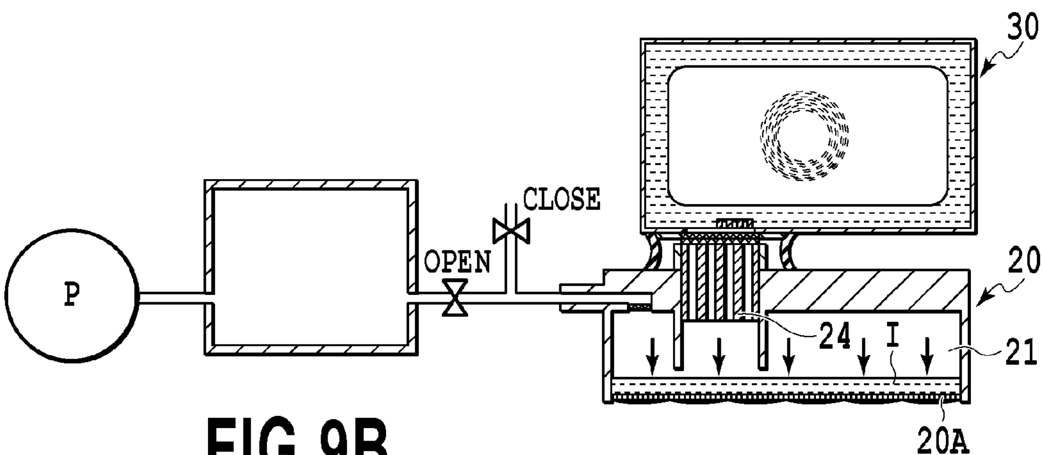


FIG.9B

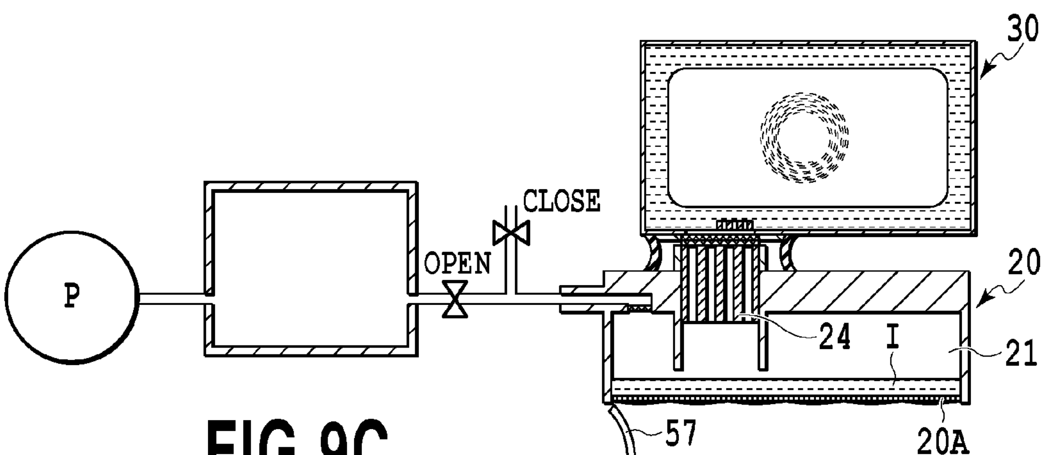


FIG.9C

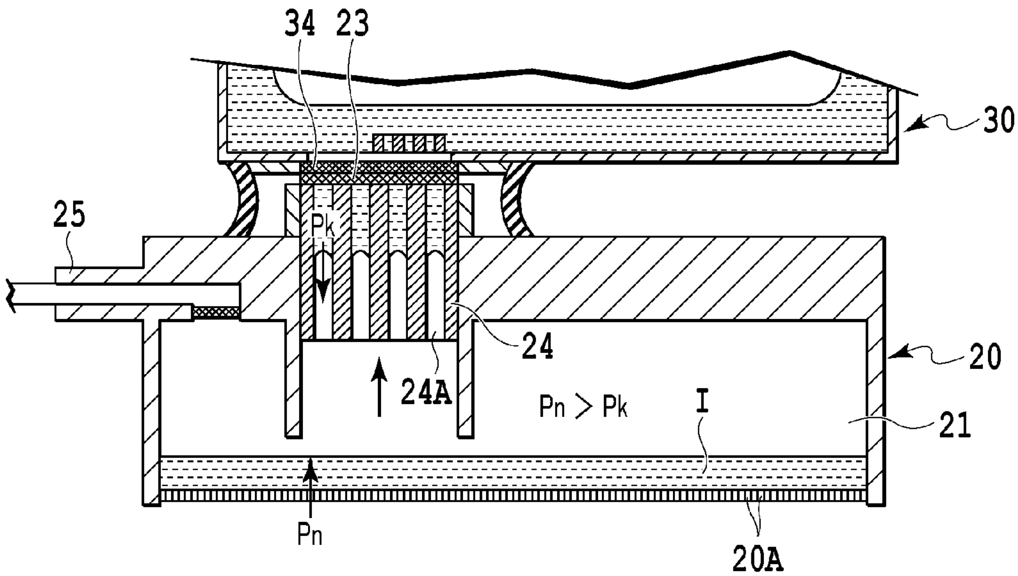


FIG.10A

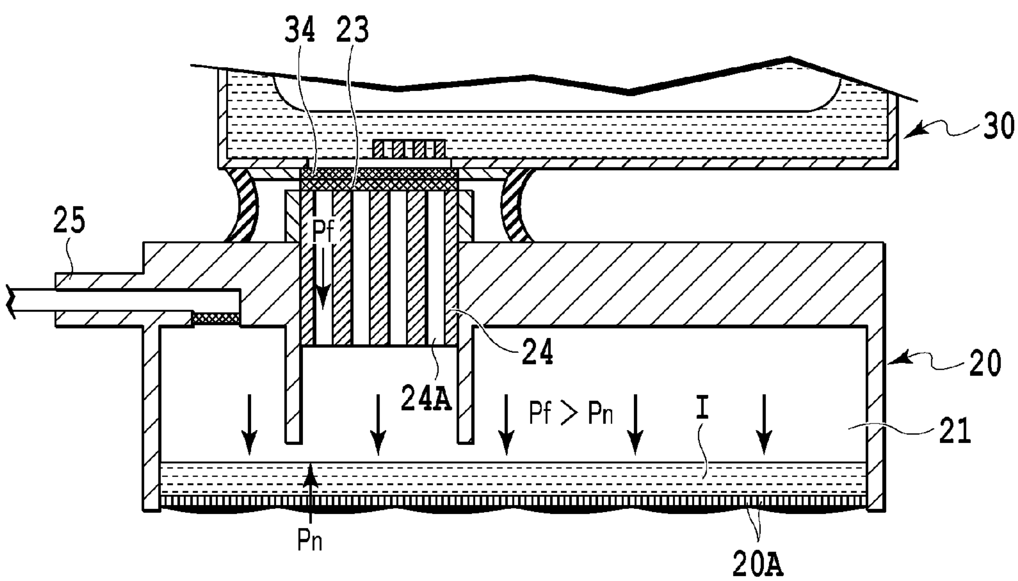


FIG.10B

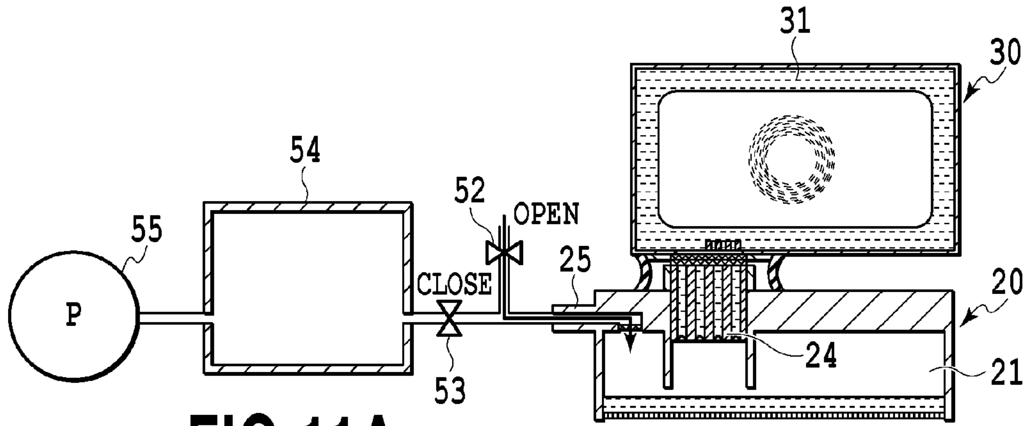


FIG.11A

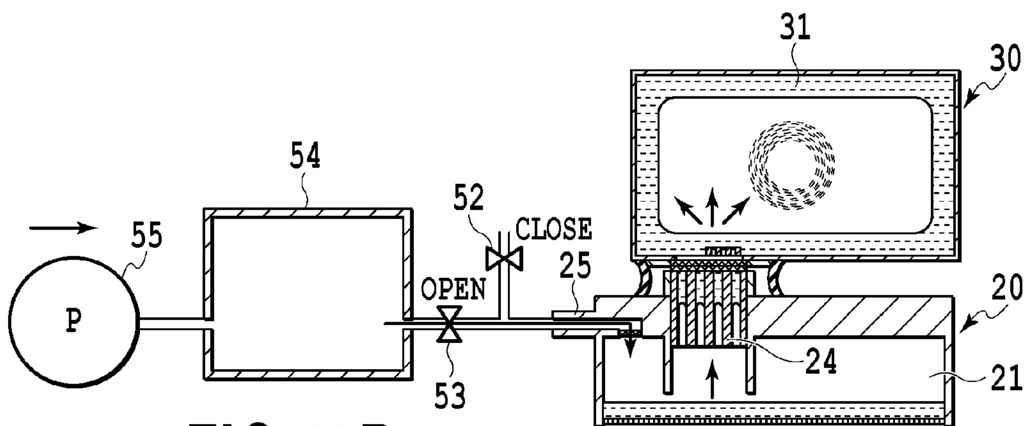


FIG.11B

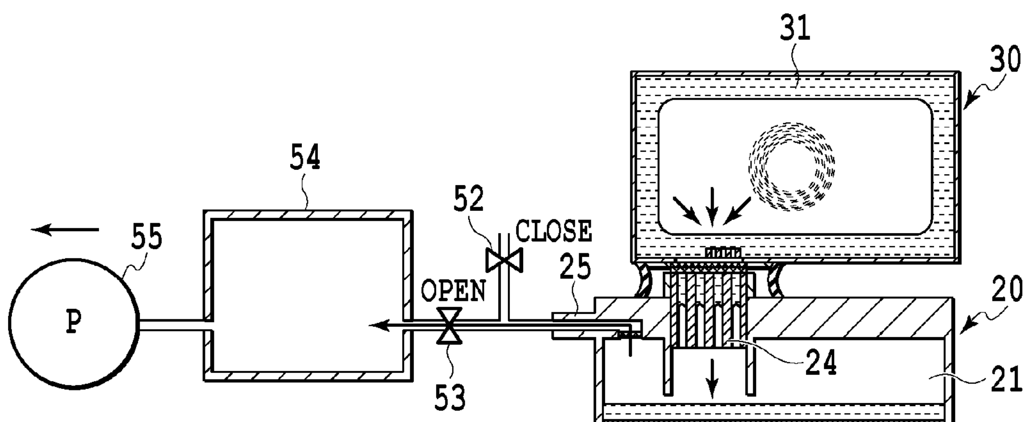


FIG.11C

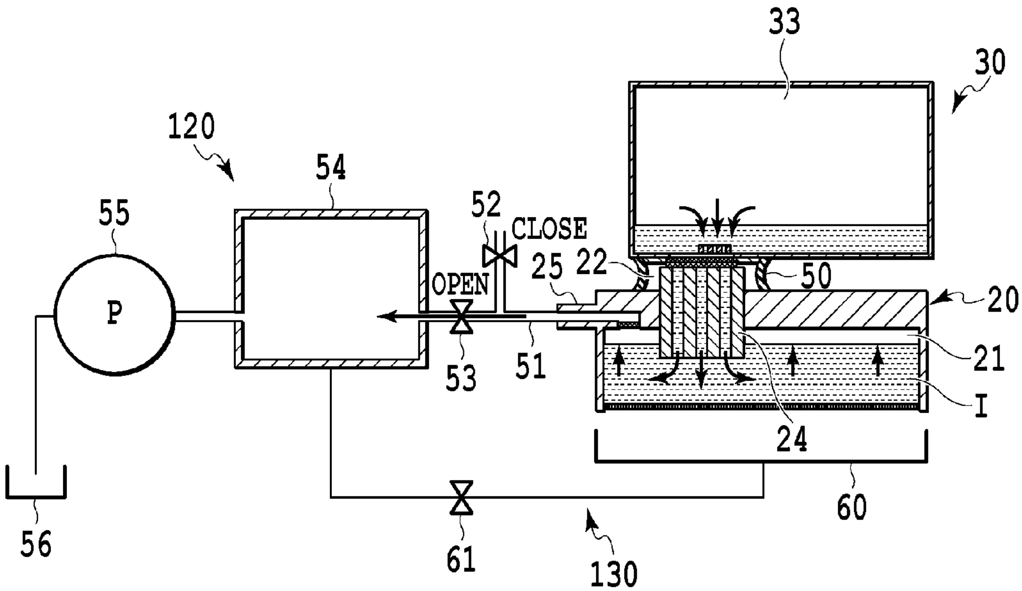


FIG.12A

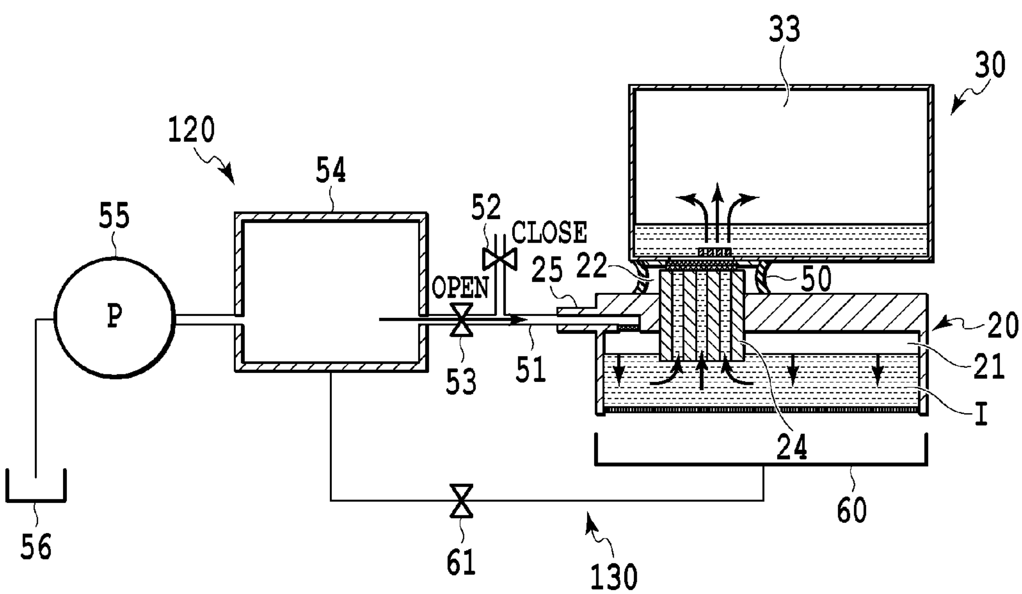


FIG.12B

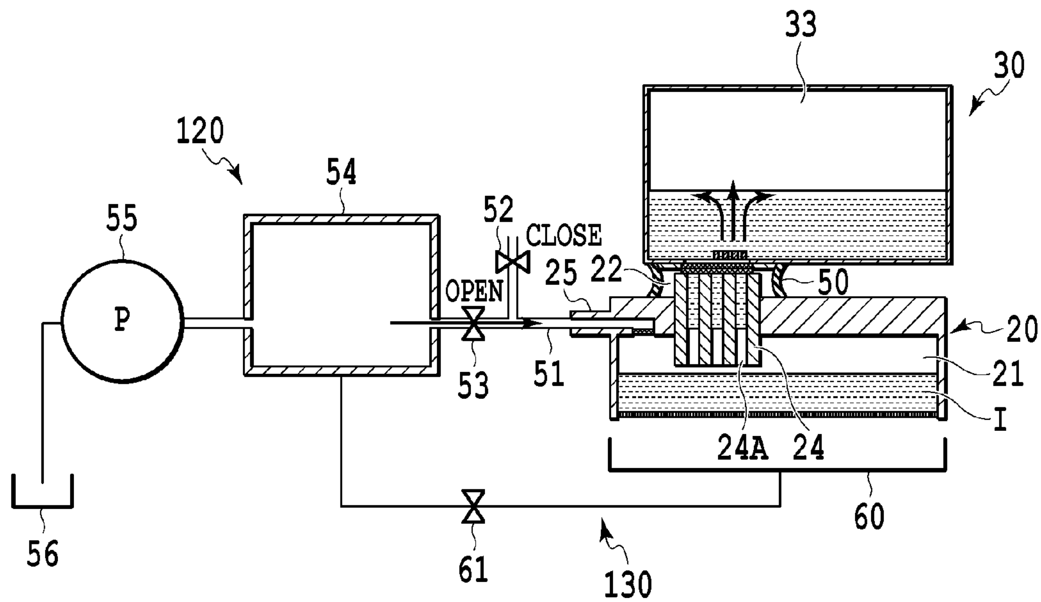


FIG.13A

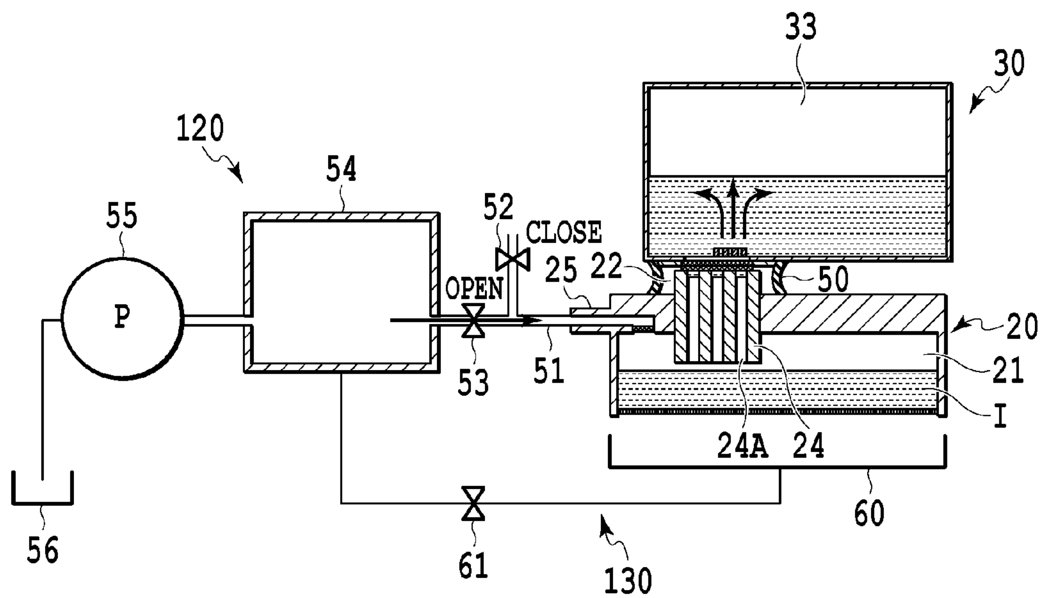


FIG.13B

LIQUID EJECTION HEAD AND LIQUID EJECTION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a liquid ejection head and a liquid ejection apparatus which are widely applicable, for example, as an ink jet print head that enables ink to be ejected and an ink jet printing apparatus including the ink jet print head.

2. Description of the Related Art

A liquid ejection head of this type generally includes liquid channels extending from an upstream side in a direction in which a liquid is fed toward ejection ports. Each of the liquid channels provides an ejection energy generating element such as an electrothermal converter (heater) or piezo element. When the liquid channel provides an electrothermal converter, heat generated by the electrothermal converter bubbles a liquid in the liquid channel, and the resulting bubbling energy can be utilized to eject the liquid through the ejection port.

Such a liquid ejection head is internally maintained at a constant negative pressure for ejecting liquid stably from the ejection port. Japanese Patent Laid-Open No. 2009-40062 describes a configuration in which a liquid is fed from a liquid tank, with a negative pressure applied to the liquid by a negative pressure generating section provided in an ink cartridge.

In the configuration described in Japanese Patent Laid-Open No. 2009-40062, the ink cartridge includes the negative pressure generating section, and the pressure (negative pressure) is applied to the inside of the liquid ejection head only by the negative pressure generating section. This precludes the pressure inside the liquid ejection head from being adjusted.

SUMMARY OF THE INVENTION

The present invention provides a liquid ejection head and a liquid ejection apparatus which allows the pressure inside a print head to be adjusted.

In the first aspect of the present invention, there is provided a liquid ejection head capable of ejecting a liquid through an ejection port, the liquid being supplied from a liquid container with a negative pressure generating section, the liquid ejection head comprising:

a liquid chamber configured to contain the liquid;

a liquid supply section configured to allow the liquid to be supplied from the liquid container to the liquid chamber; and

an opening configured to communicate with the liquid chamber and to enable the liquid and/or a gas to flow into the liquid chamber through the opening.

In the second aspect of the present invention, there is provided a liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to the first aspect of the present invention is used as the liquid ejection head, and

the apparatus comprises a transfer section configured to transfer the liquid or a gas to the opening in the liquid ejection head which communicates with the liquid chamber.

The present invention includes, besides the liquid supply section feeding the liquid into the liquid ejection head, the opening enabling the liquid and/or gas inside the liquid chamber to flow out through the opening. This allows the pressure inside the liquid ejection head to be adjusted.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic diagram of a configuration of a printing apparatus including a print head serving as a liquid ejection head according to a first embodiment of the present invention, and FIG. **1**B is a block diagram of a control system for the printing apparatus in FIG. **1**A;

FIG. **2** is a schematic diagram of a configuration of an ink supply system in the printing apparatus in FIG. **1**A;

FIG. **3** is a cross-sectional view of an ink tank in FIG. **2**;

FIG. **4** is a cross-sectional view of the print head in FIG. **2**;

FIG. **5**A is a perspective view of an ink holding member in FIG. **4**, and FIG. **5**B is a cross-sectional view taken along line VB-VB in FIG. **5**A;

FIG. **6**A is a diagram illustrating the state of the ink supply system observed when ink is stationary, and FIG. **6**B is an enlarged cross-sectional view of the ink holding member in FIG. **6**A;

FIG. **7**A, FIG. **7**B, and FIG. **7**C are each a diagram illustrating the state of the ink supply system during printing;

FIG. **8**A, FIG. **8**B, and FIG. **8**C are each a diagram illustrating the state of the ink supply system during cleaning of the print head;

FIG. **9**A, FIG. **9**B, and FIG. **9**C are each a diagram illustrating the state of the ink supply system during cleaning of the print head;

FIG. **10**A, and FIG. **10**B are each a diagram illustrating the state of the ink supply system during cleaning of the print head;

FIG. **11**A, FIG. **11**B, and FIG. **11**C are each a diagram illustrating the state of the ink supply system during stirring of ink;

FIG. **12**A and FIG. **12**B are each a diagram illustrating a part of another example of the ink stirring operation; and

FIG. **13**A and FIG. **13**B are each a diagram illustrating another part of the example of the ink stirring operation in FIG. **12**A and FIG. **12**B.

DESCRIPTION OF THE EMBODIMENTS

An embodiment of the present invention will be described below with reference to the drawings.

FIG. **1**A is a perspective view of an important part of an ink jet printing apparatus (liquid ejection apparatus) **100** to which the present invention can be applied. FIG. **1**B is a block diagram of a control system for the printing apparatus **100**. The printing apparatus **100** includes an ink jet print head **20** provided in a replaceable manner and configured to eject ink (liquid), as an embodiment of a liquid ejection head according to the present invention.

The printing apparatus **100** in the present example is what is called a full-line printing apparatus. The printing apparatus **100** can print an image on a print medium P by ejecting ink from the print head **20** while a conveying system (conveying mechanism) **110** is continuously conveying the print medium P in a direction of arrow A. The conveying system **110** in the present example conveys the print medium P using a conveying belt **110**A. However, the configuration of the conveying system **110** is not limited, and a conveying roller or the like may be used to convey the print medium P. Furthermore, in the present example, the print head **20** includes print heads

20Y, **20**M, **20**C, and **20**Bk that eject a yellow (Y) ink, a magenta (M) ink, a cyan (C) ink, and a black (Bk) ink, respectively, which are all supplied by an ink supply system (ink supply mechanism) **120** described below. This allows color images to be printed.

The printing apparatus **100** includes a recovery operation system **130** used for a recovery operation for keeping an ink ejection state of the print head **20** appropriate. The recovery operation may include a preliminary ejecting operation of ejecting ink making no contribution to image printing into a cap through ejection ports and a pressure-based recovery operation of pressurizing ink in the print head and forcibly discharging the pressurized ink into the cap through the ejection ports. The recovery operation may further include a suction-based recovery operation of sucking and discharging ink into the cap through the ejection ports and a wiping operation of wiping an ejection port surface of the print head in which the ejection ports are formed.

A CPU (control section) **101** in the printing apparatus **100** carries out processing for controlling operations of the printing apparatus, data processing, and the like. Programs for procedures for the above-described processing and the like are stored in ROM **102**. RAM **103** is used, for example, as a work area in which the processing is carried out. The CPU **101** controls the print head **20**, the conveying system **110**, the ink supply system **120**, and the recovery operation system **130** via corresponding drivers **20**A, **110**A, **120**A, and **130**A. The CPU **101** allows an image to be printed on the print medium P by ejecting ink from the print head **20** based on image data input via a host apparatus **200** such as a host computer. The CPU **101** operates the print head **20**, the conveying system **110**, the ink supply system **120**, and the recovery operation system **130** to perform control "during cleaning of the print head", control "during stirring of ink", and control "at the start of ink supply".

FIG. **2** is a diagram illustrating the ink supply system **120** and the recovery operation system **130**. FIG. **3** is an enlarged cross-sectional view of an ink tank **30** in FIG. **2**. FIG. **4** is an enlarged cross-sectional view of the print head **20** in FIG. **2**.

An ink chamber (liquid chamber) **31** in which ink is contained is formed inside the ink tank **30**, which serves as a liquid container. The ink chamber **31** forms a closed space that can communicate with the outside only at a joint portion **32**. The ink tank **30** is configured to be able to be installed in and removed from the print head **20**. Furthermore, the ink tank **30** is provided above the print head **20**. The ink chamber **31** is formed of a flexible member, and a pressure plate **33-2** connected to a spring **33-1** for negative pressure generation is incorporated in the ink chamber **31**. The spring **33-1** biases the inside of the ink chamber **31** toward the outside so as to enlarge an internal space in the ink chamber **31** via the pressure plate **33-2**. Thus, the spring **33-1** generates a predetermined negative pressure inside the ink chamber **31**. The spring **33-1**, the pressure plate **33-2**, and the ink chamber **31** provide a negative pressure generating section. The joint portion **32** is provided with a filter **34** of a nonwoven cloth.

The print head **20** includes an ejection energy generating element (not shown in the drawings) for ejecting ink I in an ink chamber **21** (a liquid in the liquid chamber) through ejection ports **20**A. The ejection energy generating element may be an electrothermal converter (heater), a piezo element, or the like. With an electrothermal converter, heat generated by the electrothermal converter bubble the ink, and the resulting bubbling energy can be utilized to eject the ink through the ejection port **20**A. Air (gas), as well as the ink I, is preset in the ink chamber **21**. Thus, the ink chamber **21** includes an ink containing section (liquid containing section) formed therein and containing the ink and an air containing section (gas containing section) also formed therein and containing air (gas).

An ink supply section (liquid supply section) **22** for communication with the ink tank (liquid tank) **30** is provided above the ink chamber **21**. A filter member **23** is provided on an opening of the supply section **22**. In the present example, the filter member **23** is formed of an SUS mesh. The mesh is configured by inweaving metal fiber, and the supply section **22** has an average width of about 10 mm. The filter member **23** is finely woven and thus prevents external dust and dirt from entering the print head. A bottom surface of the filter member **23** is pressed against an ink holding member (liquid holding member) **24** capable of holding the ink. As shown in FIG. **5**A and FIG. **5**B, a plurality of channels **24**A each with a circular cross section is formed inside the ink holding member **24**. Each of the channels **24**A has a diameter of about 1.0 mm.

Furthermore, the ink chamber **21** includes an opening **25** provided in an upper portion of the ink chamber **21** and which can be connected to a transfer section **51** serving as an external channel to transfer the gas and/or liquid. The opening **25** is provided with a filter **26**. The opening **25** is configured to enable the liquid (ink) or gas in the ink chamber **21** to flow out to the outside through the opening **25**. The opening **25** also enables both the liquid (ink) and gas in the ink chamber **21** to flow out through the opening **25**. Additionally, the opening **25** is configured to enable the liquid (ink) or gas outside the print head **20** to flow into the opening **25**. Moreover, the opening **25** is configured to enable both the liquid (ink) and gas outside the print head **20** to flow into the opening **25**.

The print head **20** and the ink tank **30** are coupled together as shown in FIG. **2**. That is, the supply section **22** of the print head **20** and the joint portion **32** of the ink tank **30** are coupled together so the filter member **23** on the print head **20** side and the filter **34** on the ink tank **30** side are compressed against each other in the vertical direction. Such a coupled portion between the print head **20** and the ink tank **30** is kept closed by being circumferentially surrounded by an elastic cap member **50** formed of rubber. In the present example, the print head **20** and the ink tank **30** are directly connected together, and thus, an ink supply path (liquid supply path) between the print head **20** and the ink tank **30** is very short.

The transfer section **51** connected to the opening **25** of the print head **20** is divided into two branches. One of the branches is in communication with the outside air via an openable and closable valve **52**. The other branch is in communication with a buffer chamber **54** via an openable and closable valve **53**. A space of about 10 mL is formed in the buffer chamber **54** and is in communication with a waste ink tank **56** through a pump **55**. The pump **55** is a transfer section which serves as means for transferring the liquid (ink) and/or gas (air) and which pumps the liquid (ink) and/or gas (air) into and out from the print head **20**. In the present example, a tube pump capable of forward and reverse rotations is used as the pump **55**.

A cap **60** is connected to the buffer chamber **54** via an openable and closable valve **61**. The cap **60** can come into tight contact with a surface (ejection port formation surface) of the print head **20** in which the ejection ports **20**A are formed. When the cap **60** is internally sucked using the pump **55** with the ejection ports **20**A capped by the cap **55**, the ink can be sucked and discharged into the cap **60** through the ejection ports **20**A (suction-based recovery operation). Furthermore, the following are possible: a preliminary ejection operation of ejecting ink making no contribution to image printing into the cap **60** through the ejection ports **20**A and a pressure-based recovery operation of pressurizing the ink in the print head **20** to forcibly discharge the ink into the cap **60** through the ejection ports **20**A. During the pressuring recovery operation, a pressurizing force generated using the pump **55** can be exerted into the print head **20** through the buffer chamber **54** and the valve **53**. The ink contained in the cap **60** as result of the recovery operation can be discharged into the waste ink tank **56** (see FIG. **2**) by a suction force generated using the pump **55**.

Now, description will be provided which relates to the state of the printing apparatus while the ink is stationary, during a printing operation, during cleaning of the print head, during stirring of the ink, and at the start of ink supply.

(While the Ink is Stationary)

While the ink is stationary, for example, while the printing apparatus is stopped, the valves **52** and **53** are closed as shown in FIG. **6**A. Ink is filled in the channels **24**A of the ink holding member **24**. The ink chamber **21** in the print head **20** is internally at a predetermined negative pressure. Ink meniscuses formed in the ejection ports **20**A are maintained. Ink meniscuses are formed in the channels **24**A of the ink holding member **24** as shown in FIG. **6**B. Forces Pt, Ph, Pk, and Pg act on the meniscuses in the channels **24**A of the ink holding member **24**. The force Pt results from the negative pressure in the ink tank **30** to draw in the meniscuses toward the ink tank side. The force Ph results from the negative pressure in the print head **20** to draw the meniscuses into the print head. The force Pk is a meniscus force resulting from the surface tension of the ink to draw in the ink toward the ink tank side. The force Pg results from the weight of the ink to move the ink downward. The forces are balanced to maintain the meniscuses formed in the ink holding member **24**, keeping the ink in the print head **20** stationary.

(During a Printing Operation)

During a printing operation by the printing apparatus, the valves **52** and **53** are closed as shown in FIG. **7**A, FIG. **7**B, and FIG. **7**C. When the ink is ejected through the ejection ports **20**A as shown in FIG. **7**A, the ink I in the ink chamber **21** is consumed to further reduce the pressure in the ink chamber **21** as shown in FIG. **7**B. The thus increasing negative pressure in the ink chamber **21** acts as a force in a direction in which the ink in the channels **24**A in the ink holding member **24** is drawn into the ink tank **30**. When the negative pressure in the ink chamber **21** increases to a predetermined negative pressure or higher, the ink meniscuses formed in the channels **24**A of the ink holding member **24** are broken to allow the ink in the ink tank **30** to be supplied to the print head **20** as shown in FIG. **7**C. The supply of the ink reduces the negative pressure in the ink chamber **21** to form meniscuses again in the channels **24**A of the ink holding member **24** as shown in FIG. **7**A. The supply of the ink is then stopped. Thus, the ink is fed from the ink tank **30** into the ink chamber **21** in the print head **20** according to ink consumption.

The meniscus force Pk of the meniscus formed in each of the channels **24**A of the ink holding member **24** acts as a force against the flow of the ink fed from the ink tank **30** to the print head **20**. Thus, when the meniscus force Pk is excessively strong, the ink supply is hindered to degrade ink supply performance. The meniscus force P of the meniscus of the liquid formed in the opening of the liquid channel can be expressed by Formula 1 when the surface tension is denoted by γ, the radius of the opening is denoted by r, and the contact angle of the ink in the liquid channel is denoted by θ.

$$P = \frac{2\gamma\cos\theta}{r} \qquad \text{(Formula 1)}$$

Furthermore, when the opening of the channel is not circular, the meniscus force P in the opening has a relation with a circumferential length L and an opening area S which is expressed by Formula 2 (the meniscus force P is proportional to L/S). Even if the opening is not truly circular, the theoretical formula in Formula 1 is applicable regardless of the shape of the opening when the opening is assumed to be a circular tube having an area as that of the opening and a radius r.

$$P \propto L/S \qquad \text{(Formula 2)}$$

Thus, the meniscus force P decreases with increasing radius r of the opening of the liquid channel.

The plurality of channels **24**A each with an inner diameter of about 1 mm is formed in the ink holding member **24** according to the present embodiment in a penetrating manner. The inner diameter of the channel **24**A is set such that the meniscus force of the ink in the channel **24**A is weaker than the meniscus force of the ink in the filter members **23** and **34**. When the ink is supplied in association with a printing operation, no ink meniscus is formed in the filter members **23** and **24**. This allows the ink supply performance to be improved so as to enable high-speed printing.

If the ink holding member **24** is not provided, meniscuses are formed in the filter member **23** or **34**, degrading the ink supply performance. Specifically, the inner diameter of each of the ink channels formed in the filter members **23** and **34** is about one-thousandth of the inner diameter of the channel **24**A of the ink holding member **24**, and thus, the meniscus force in the ink channels in the filter members **23** and **34** is about 1,000 times as strong as the meniscus force in the channel **24**A. Thus, without the ink holding member **24**, the ink supply performance is significantly degraded.

(During Cleaning of the Print Head)

When the ejection port formation surface of the print head **20** is wiped and cleaned, the print head **20** is internally pressurized to push the ink I in the ink chamber **21** out through the ejection ports **20**A to improve the lubricity of the ejection port formation surface.

First, as shown in FIG. **8**A, the valve **52** is opened to admit the outside air into the print head **20**, thus releasing the negative pressure in the ink chamber **21**. Then, as shown in FIG. **8**B, the pump **55** is rotated in one direction with the valves **52** and **53** closed to feed air into the buffer chamber **54**, thus pressurizing the buffer chamber **54**. Then, as shown in FIG. **8**C, the valve **53** is opened to admit the pressurized air in the buffer chamber **54** into the print head **20**, thus pressuring the inside of the ink chamber **21**. At this time, if, for example, the liquid (ink) is mixed in the buffer chamber **54** or the transfer section **51**, the liquid (ink) and/or gas (air) flows into the print head **20**.

The internal pressurization of the ink chamber **21** moves the ink in the channels **24**A of the ink holding member **24** and the ink in the ink chamber **21** as shown in FIG. **9**A and FIG. **9**B.

A relation shown below is set for the inner diameter Df of each ink channel formed in the filter member **23** on the print head side, the inner diameter Dk of each channel **24**A in the ink holding member **24**, and the inner diameter Dn of each ejection port **20**A.

$$Df < Dn < Dk$$

Thus, a relation shown below is set for the meniscus force Pf in the filter member **23** on the print head side, the meniscus force Pk in the channel **24**A of the ink holding member **24**, and the meniscus force Pn in the ejection port **20**A.

$$Pf>Pn>Pk$$

If the ink chamber **21** is internally pressurized, then as shown in FIG. **9**A, the meniscuses in the channels **24**A of the ink holding member **24** move backward, that is, upward in FIG. **9**A. The meniscuses reach the filter member **23**, and then, the ink is pushed out through the ejection ports **20**A as shown in FIG. **9**B. More specifically, first, the meniscuses in the ink holding member **24**, which exert the weak meniscus force Pk, move backward to allow the ink in the channels **24**A to flow backward into the ink tank **30** as shown in FIG. **10**A. As shown in FIG. **10**B, all of the ink in the channels **24**A is returned into the ink tank **30** to form meniscuses in the filter member **23**. The meniscus force Pn in the ejection ports **20**A is weaker than the meniscus force Pf in the filter member **23**, and thus, the ink in the ink chamber **21** is pushed out through the ejection ports **20**A as shown in FIG. **10**B.

The ink chamber **21** is internally pressurized to a pressure Pc. When the pressure Pc is higher than the meniscus force Pk, the meniscuses in the ink holding member **24** are moved toward the ink tank **30** side, and the ink is pushed out through the ejection ports **20**A without moving the meniscuses in the filter member **23**, which have the meniscus force Pf. Thus, the ink can be pushed out through the ejection ports **20**A without moving the meniscuses in the filter member **23**, in other words, without pushing the air in the print head into the ink tank.

After the ejection port formation surface is sufficiently wetted with the ink pushed out as described above or while the ink is being pushed out through the ejection ports **20**A, the ejection port formation surface is wiped by a plate-like cleaning member **57** as shown in FIG. **9**C. This allows the capability of cleaning the ejection port formation surface to be improved. The cleaning member **57** is, for example, formed of urethane rubber and moves in a lateral direction in FIG. **9**C while keeping in contact with the ejection port formation surface. Such movement may involve movement of at least either the cleaning member **57** or the print head **20**.

After the wiping operation by the cleaning member **57**, the pump **55** is reversely rotated to introduce a negative pressure into the print head **20**. Thus, the liquid (ink) and/or gas (air) flows out from the print head **20**, enabling such a state as shown in FIG. **6**A and FIG. **6**B to be recovered.

(During Stirring of Ink)

When the ink tank **30** is left untouched for a long period of time, the components of the ink inside the ink tank **30** may become nonuniform. In particular, if the ink in the ink tank **30** is pigment ink, a color material precipitates in a lower portion of the ink tank **30**, leading to the risk of changing the density of a printed image. According to the present embodiment, the ink in the channels **24**A of the ink holding member **24** is drawn into and out from the ink tank **30** in order to make the components of the ink in the ink tank **30** uniform.

First, as shown in FIG. **11**A, the valve **52** is opened to open the ink chamber **21** in the print head **20** to the atmosphere. Then, as shown in FIG. **11**B, the valve **52** is closed and the valve **53** is opened, and then, the pump **55** is rotated in one direction to pressurize the inside of the ink chamber **21**. The ink chamber **21** is pressurized up to a pressure Ps. The pressure Ps has a magnitude sufficient to move the meniscuses in the ink holding member **24**, which have the meniscus force Pk, without pushing the ink out through the ejection ports **20**A or moving the meniscuses in the filter member **23**, which have the meniscus force Pf. Such a pressure Ps returns the ink in the channels **24**A of the ink holding member **24** to the ink tank **30** as shown in FIG. **11**B. The returned ink disturbs the ink components precipitated in a lower layer in the ink tank **30**. As a result, the ink in the ink tank **301** can be stirred.

Thereafter, the pump **55** is reversely rotated to reduce the pressure in the print head **20**, thus drawing the ink in the ink tank **30** into the channels **24**A of the ink holding member **24** again, as shown in FIG. **11**C. Thus, the ink positioned in an upper layer in the ink tank **30** can be drawn downward to stir the ink in the ink tank **30**.

Such pressurization and pressure reduction in the print head **20** are repeated to draw the ink in the channels **24**A of the ink holding member **24** into and out from the ink tank **30** a desired number of times. Then, the ink in the ink tank **30** can be sufficiently stirred to make the ink components uniform.

Furthermore, ink may be fed from the ink tank **30** into the ink chamber **21** until the level of the ink I in the ink chamber **21** becomes higher than a bottom surface of the ink holding member **24**. Then, the ink I in the ink chamber **21** may be fed back to the ink tank **30** through the channels **24**A of the ink holding member **24**. This enables an increase in the amount of ink fed into and from the ink tank **30** to allow the ink in the ink tank to be effectively stirred. A specific example of such an ink stirring operation will be described using FIG. **12**A, FIG. **12**B, FIG. **13**A, and FIG. **13**B.

First, as shown in FIG. **12**A, the pump **55** is reversely rotated with the valve **52** closed and the valve **53** open to discharge the gas in the ink chamber **21**, thus reducing the pressure in the ink chamber **21** to generate a negative pressure. Consequently, ink is fed from the ink tank **30** into the ink chamber **21**. Then, ink is fed from the ink tank **30** into the ink chamber **21** until an ink amount sensor (not shown in the drawings) which detects the amount of the ink I in the ink chamber **21** detects that the level of the ink I in the ink chamber **21** is higher than the bottom surface of the ink holding member **24**. The ink amount sensor may be, for example, a level sensor including a plurality of electrodes in the ink chamber **21**. The level sensor is configured to detect the level of ink by allowing the electrodes to be made electrically continuous or discontinuous by the ink when the surface of the ink reaches a predetermined position. Additionally, the ink amount sensor may be able to detect the amount of the ink I in the ink chamber **21**, and is not limited to a configuration that detects the level of ink.

After ink is supplied until the level of the ink I becomes higher than the bottom surface of the ink holding member **24**, the pump **55** is rotated in one direction to introduce the gas into the ink chamber **21** to pressurize the inside of the ink chamber **21** as shown in FIG. **12**B. Thus, the ink in the ink chamber **21** is fed back to the ink tank **30** through the channels **24**A of the ink holding member **24**. Subsequently, as shown FIG. **13**A, the surface of the ink I in the ink chamber **21** leaves the bottom surface of the ink holding member **24**. Then, as shown in FIG. **13**B, the ink in the channels **24**A of the ink holding member **24** is fed back to the ink tank **30**.

As described above, the operation of stirring ink by feeding the ink into and from the ink tank **30** may be repeated a predetermined number of times. Furthermore, such an ink stirring operation enables an increase in the amount of ink fed into and from the ink tank **30** during one stirring operation compared to the operation in FIG. **11**A, FIG. **11**B, and FIG. **11**C in which the ink in the channels **24**A of the ink holding member **24** is fed into and from the ink tank **30**. As a result, the ink in the ink tank **30** can be more effectively stirred.

Furthermore, when the ink I in the ink chamber **21** is fed back to the ink tank **30** using the pump **55**, the inside of the ink chamber **21** may be intermittently pressurized or the pressure in the ink chamber **21** may be changed (increased or reduced).

Moreover, the amount of ink fed into and from the ink tank **30** may be changed in accordance with the length of the period for which the ink tank **30** is left uncontrolled. For example, the amount of ink fed from the ink tank **30** into the ink chamber **21** may be increased consistently with the length of the period for which the ink tank **30** is left uncontrolled. Subsequently, the amount of ink fed back from the ink chamber **21** to the ink tank may be increased. Furthermore, such an ink stirring operation as shown in FIG. **11**A, FIG. **11**B, and FIG. **11**C and such an ink stirring operation as shown in FIG. **12**A, FIG. **12**B, FIG. **13**A, and FIG. **13**B may be performed in a switchable manner in accordance with the length of the period for which the ink tank **30** is left uncontrolled. Furthermore, the amount of ink fed into and from the ink tank **30** may be changed not only during one stirring operation but also in accordance with the number of times the stirring operation has been performed.

(At the Start of Ink Supply)

When the ink tank **30** is connected to the print head **20** with no ink present therein, a capping state is established in which the cap **60** is in tight contact with the ejection port formation surface of the print head **20**. Then, the cap **60** is internally sucked using the pump **55**. Thus, as shown in FIG. **6**A, the ink in the ink tank **30** can be supplied to the print head **20**. Furthermore, the ink in the ink tank **30** can be supplied to the print head **20** by generating a negative pressure using the pump **55** so that the negative pressure acts in the ink chamber **21** through the buffer chamber **54**, the valve **53**, and the opening **25**. When the cap **60** is used for the suction as in the above-described former case, ink making no contribution to image printing is discharged into the cap **60** as is the case with the suction-based recovery operation. On the other hand, when the suction is carried out through the opening **25** as in the above-described latter case, the ink can be fed into the print head **20** without discharging the ink, making no contribution to image printing, thus suppressing ink consumption.

The amount of ink fed into the print head **20** can be adjusted to an optimum amount using an ink amount sensor (a fluid level sensor for ink; not shown in the drawings) that detects the amount of ink in the ink chamber **21**. Ink meniscuses can be formed in the ejection ports **20**A by performing the suction-based recovery operation of internally sucking the cap **60** in the capping state using the pump **55**.

Furthermore, if the ink in the ink tank **30** connected to the print head **20** is exhausted to reduce the amount of ink in the print head **20**, when a new ink tank **30** is connected to the print head **20**, the amount of ink in the print head **20** needs to be increased to the optimum value. In this case, the ink in the newly connected ink tank **30** can be fed into the print head **20** by introducing, through the opening **25**, a negative pressure generated using the pump **55**. Furthermore, when the amount of ink in the print head **20** decreases to the degree that the ink amount sensor fails to detect the amount, the ink in the ink tank **30** can be fed into the print head **20** by introducing a negative pressure into the print head **20** through the opening **25**.

As described above, the ink can be fed into the print head **20** without wasteful ink consumption by introducing a negative pressure (a suction force used to reduce the pressure in the print head **20**) into the print head **20**. During such ink supply, the cap may be in the capping state.

According to the above-described embodiment, the ink holding member **24** is provided on the print head **20** side. However, the ink holding member **24** may be provided on the ink tank **30** side or in a print head installation portion on the printing apparatus side on which the print head **20** is installed. Similarly, the filter member **23** may be provided on the ink tank **30** side or in the print head installation portion on the printing apparatus side on which the print head **20** is installed.

Furthermore, the pressure in the print head **20** may be controlled through the opening **25** in order to reduce a variation in the negative pressure in the print head **20** during a printing operation. When a pressure is applied to the inside of the print head **20**, the opening **25** functions as an applied pressure introducing section that allows an applied pressure to be introduced into the print head **20** by introducing the gas and/or liquid through the opening **25**. The transfer section **51** functions as an applied pressure supply path that enables the supply of an applied pressure. Additionally, when a suction (pressure reduction) force is applied to the inside of the print head **20**, the opening **25** functions as a suction force introducing section that allows a suction force to be introduced into the print head **20** by discharging the gas and/or liquid through the opening **25**. The transfer section **51** functions as a suction force supply path that enables the supply of a suction force. The opening **25** may be divided into an introduction section for pressurization and a discharge section for suction. In addition, the applied pressure and the suction force may be a pressure that applies a force to the inside of the print head **20** and a pressure that serves to reduce the pressure in the print head **20**, respectively, and are not necessarily limited to a positive pressure and a negative pressure based on the atmospheric pressure.

The present invention can be applied to, besides the full-line printing apparatus, various other printing apparatuses based on the respective printing schemes such as a serial scan printing apparatus that prints an image by moving the print head and performing an operation of conveying the print medium.

Furthermore, the liquid ejection head according to the present invention is not only applicable as an ink jet print head capable of ejecting ink but also widely applicable as a head for ejecting any of various liquids. For example, the liquid ejection head according to the present invention can be used as a head for ejecting any of various process liquids or drugs supplied to a liquid channel. Additionally, the liquid ejection apparatus according to the present invention is not only applicable as an ink jet printing apparatus using an ink jet print head but also widely applicable as an apparatus that applies any of various process liquids or drugs to a processing target member.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application Nos. 2013-060517, filed Mar. 22, 2013 and 2014-005229, filed Jan. 15, 2014 which are hereby incorporated by reference herein in their entirety.

What is claimed is:

1. A liquid ejection head capable of ejecting a liquid through an ejection port, the liquid ejection head comprising:

a liquid chamber configured to contain the liquid; and

a liquid supply section configured to allow the liquid to be supplied from a liquid container to the liquid chamber,

wherein a negative pressure in the liquid chamber is made by a negative pressure generating section of the liquid container, the liquid container being detachably attached to the liquid ejection head, the liquid ejection head comprises an opening configured to communicate with the liquid chamber and to enable at least a gas to flow into the liquid chamber through the opening, and

the opening is driven based on a control signal, the control signal for opening the opening being not outputted in a case where the liquid is ejected from the liquid ejection head.

2. The liquid ejection head according to claim **1**, wherein the liquid chamber comprises a liquid containing section configured to contain the liquid and a gas containing section configured to contain the gas, and

the opening is in communication with the gas containing section.

3. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **2** is used as the liquid ejection head, and

the apparatus comprises a transfer section configured to transfer the gas to the gas containing section through the opening.

4. The liquid ejection head according to claim **1**, wherein the liquid chamber comprises a liquid containing section configured to contain the liquid and a gas containing section configured to contain the gas, and

the liquid supply section is in communication with the gas containing section, and the negative pressure generating section applies the negative pressure to an inside of the liquid chamber.

5. The liquid ejection head according to claim **1**, further comprising a liquid holding member with a channel formed therein to allow the liquid supply section and the liquid chamber to communicate with each other, the liquid holding member enabling the liquid to be held therein,

wherein a meniscus of the liquid formed in the channel has a smaller meniscus force than that of a meniscus of the liquid formed in the ejection port.

6. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **5** is used as the liquid ejection head, and

the apparatus comprises a transfer section configured to transfer at least the gas to the liquid chamber through the opening to a degree that a meniscus in the channel is migrated, whereas a meniscus in the ejection port is held.

7. The liquid ejection head according to claim **1**, wherein the liquid supply section comprises a filter member, and

a meniscus of the liquid formed in the filter member has a larger meniscus force than that of the meniscus of the liquid formed in the ejection port.

8. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **7** is used as the liquid ejection head, and

the apparatus comprises a transfer section configured to transfer at least the gas to the liquid chamber through the opening to a degree that a position of a meniscus in the ejection port migrates, whereas a position of a meniscus in the filter member is maintained.

9. The liquid ejection head according to claim **1**, further comprising a detecting section configured to detect the amount of the liquid in the liquid chamber.

10. The liquid ejection head according to claim **9**, wherein the detecting section is provided to detect a height of a surface of the liquid in the liquid chamber.

11. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **1** is used as the liquid ejection head, and

the apparatus comprises:

a transfer section configured to transfer at least the gas to the liquid chamber in the liquid ejection head through the opening which communicates with the liquid chamber; and

a control unit configured to cause the opening to open and close based on the control signal.

12. The liquid ejection apparatus according to claim **11**,

wherein the opening is opened to allow the liquid chamber and the outside of the liquid chamber to communicate with each other and then closed based on the control signal.

13. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **1** is used as the liquid ejection head, and

the apparatus comprises:

a transfer section configured to transfer at least the gas to the liquid chamber through the opening of the liquid ejection head; and

a liquid supply path configured to enable the liquid with a negative pressure applied thereto to be fed to the liquid supply section.

14. A liquid ejection head capable of ejecting a liquid through an ejection port, the liquid ejection head comprising:

a liquid chamber configured to contain the liquid; and

a liquid supply section configured to allow the liquid to be supplied from a liquid container to the liquid chamber,

wherein a negative pressure in the liquid chamber is made by a negative pressure generating section of the liquid container, the liquid container being detachably attached to the liquid ejection head,

the liquid ejection head comprises an opening configured to communicate with the liquid chamber and to enable at least a gas to flow into the liquid chamber through the opening, and

a pressure in the liquid chamber is regulated to at least a first range when the liquid is ejected from the liquid ejection head and a second range different from the first range.

15. The liquid ejection head according to claim **14**, wherein the liquid chamber comprises a liquid containing section configured to contain the liquid and a gas containing section configured to contain the gas, and

the opening is in communication with the gas containing section.

16. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **15** is used as the liquid ejection head, and the apparatus comprises a transfer section configured to transfer the gas to the gas containing section through the opening.

17. The liquid ejection head according to claim **14**, wherein the liquid chamber comprises a liquid containing section configured to contain the liquid and a gas containing section configured to contain the gas, and

the liquid supply section is in communication with the gas containing section, and the negative pressure generating section applies the negative pressure to an inside of the liquid chamber.

18. The liquid ejection head according to claim **14**, further comprising a liquid holding member with a channel formed therein to allow the liquid supply section and the liquid chamber to communicate with each other, the liquid holding member enabling the liquid to be held therein,

wherein a meniscus of the liquid formed in the channel has a smaller meniscus force than that of a meniscus of the liquid formed in the ejection port.

19. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **18** is used as the liquid ejection head, and

the apparatus comprises a transfer section configured to transfer at least the gas to the liquid chamber through the opening to a degree that a meniscus in the channel is migrated, whereas a meniscus in the ejection port is held.

20. The liquid ejection head according to claim **14**, wherein the liquid supply section comprises a filter member, and

a meniscus of the liquid formed in the filter member has a larger meniscus force than that of the meniscus of the liquid formed in the ejection port.

21. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **20** is used as the liquid ejection head, and

the apparatus comprises a transfer section configured to transfer at least the gas to the liquid chamber through the opening to a degree that a position of a meniscus in the ejection port migrates, whereas a position of a meniscus in the filter member is maintained.

22. The liquid ejection head according to claim **14**, further comprising a detecting section configured to detect the amount of the liquid in the liquid chamber.

23. The liquid ejection head according to claim **22**, wherein the detecting section is provided to detect a height of a surface of the liquid in the liquid chamber.

24. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **14** is used as the liquid ejection head, and

the apparatus comprises:

a transfer section configured to transfer at least the gas to the opening in the liquid ejection head which communicates with the liquid chamber; and

a control unit configured to cause the opening to open and close based on the control signal.

25. The liquid ejection apparatus according to claim **24**,

wherein the opening is opened to allow the liquid chamber and the outside of the liquid chamber to communicate with each other and then closed based on control signal.

26. A liquid ejection apparatus configured to use a liquid ejection head configured to enable a liquid to be ejected to apply the liquid ejected from the ejection head to a print medium,

wherein the liquid ejection head according to claim **14** is used as the liquid ejection head, and

the apparatus comprises:

a transfer section configured to transfer at least the gas to the liquid chamber through the opening of the liquid ejection head; and

a liquid supply path configured to enable the liquid with a negative pressure applied thereto to be fed to the liquid supply section.

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